"The essential quality of the great technological revolution is the creation of the new habitat of human existence." (Rosalind Williams)

With this invited paper I return to Novática, after 15 years, with the basic message that now, less than ever, we can't separate infotechnology from society, an idea that without any doubt is in the mind of all infoprofessionals, but frequently without a degree of conviction and sufficient concreteness. In this occasion I appear with the purpose of briefly explaining a conceptual tool designed for helping to globally understand the architecture of the infotechnology and some of the keys that determine its impact in society.

In my 36 years in the educating field, as professor of thousands of telecommunication engineers and of some computer engineers, I have observed that in their first seven years of experience, a great majority of them, has had technology itself as a dominant mental horizon in their work, a much smaller percentage "sees", or has seen, technology mainly as a mean for a practical finality, for example a business application, and those who have directed their finalist sights towards a not so immediate social aim, more general and more abstract, are few.

In a way, their role constitute a reflection of the teaching received. With the passing of time, their personal evolution will have transformed their attitudes, in benefit of more social criteria, but I believe that frequently lived intimately like a personal defeat confronting an unavoidable reality. In recent years, nevertheless, reality has transformed in such a way, that it is necessary to revise some of the assumptions which that teaching has been based on.

The social environment, as an immense silicon die

Precisely when someone is an education professional, he has to evaluate continuously if his/her assignment complies with the educational function that corresponds to the reality of every moment. My professional responsibility has impelled me to reflect on the education of the telecommunication and computer engineers. I have participated in the elaboration of four university curricula and I have written a few articles on the matter, one of them in Novática, in 1984. My last article in these areas, titled "Future hybrid engineers" (http://www.gsi.dit.upm.es/~fsaez/OtrosArticulos/futurosingenieros.html), has been published in the 'BIT' magazine, issue 144, April-May 2004, of the Colegio Oficial de Ingenieros de Telecomunicación, in which, besides saying a strong "no" to a future four-academic-years engineering degree, I pronounce myself in the necessity of formulating three different kinds of 'infoengineers' (or master-degree 'infotechnicians' as a generalization), the third being the one I call hybrid, for lack of a more appropriate name.

I write there that in a so extremely interrelated, technified and fast paced world, in all of its economic, political, social, and vital facets, the growing swarm of sociotechnical problems, where the technical dimensions of a reality permeated by infotechnology combine with the multiple and more complex social and human factors, require a new class of technicians. The world changes, the technicians have to change, the technological innovation has to affect them more than anybody.

At the time I'm writing this article, from time to time I read "Cultura y cambio tecnológico" (original title in english: "Retooling: a Historian Confronts Technological Change") by Rosalind Williams, Alianza Editorial, Madrid, 2004, and in its second chapter titled "The expansive disintegration of the engineering" talks about the identity crisis of engineering, produced by the deep and rapid social and technoscientific changes. Personally, I visualize these changes identifying them with three milestones of my own life, with a 20 year interim between them.

The first one corresponds to my return in the summer of 1964 from a two month scholarship in a French center of advanced research, hoarding in my luggage a few three-pin transistors, with which I showed off to my schoolmates of engineering, who had never even seen one. In 1984, I got my first personal computer, when microprocessors and integrated circuits with millions of transistors (only visible to the electronic microscope) in a silicon die were commonly used. That is my second image, and the third one, dated 2004 for instance, more diffused in its proportions, but intellectually clear, was to observe how the infotechnology infrastructure, borne by scores of thousands of millions of integrated circuits, which were composed at the same time by myriads of those transistors that I proudly exhibited in 1964, was integrated within the social environment. It was integrated, built-in, embedded, any way you want to call it, in the same way, conceptually speaking, the transistors are integrated in a silicon die. Therefore, it is more appropriate to call it technosocial environment, as it is not a capricious play of words.

The two first images - as we all of us know - symbolize such a number of expansive phases in electronics, informatics and communications. For us, educators and researchers, they have meant huge challenges toward the educational re-engineering, the design of new curricula and the technical updating which, as a whole, have been responded from both, the institutional and the personal, levels.

But the third image symbolizes another phase, radically different and of unknown horizons, where the complexity and the imbrication of technoscientific and social dimensions join get together. The "new habitat of human existence", that I have called New Technosocial Environment (NET, in its Spanish acronym), favored by technology, demands new, explanatory principles, new ideas and new strategies that do it safe, equitable and livable. For that reason, I have no doubt that a quantitative reasonable segment of our future graduates should receive an education and a mentallization toward more systemic, socioeconomic and political responsibilities, capable of contributing an integrated vision of the techniques into the social framework. In my article cited up I have written that "the expansive reality, the vitality, push and convergence of the technologies, taking over an extensive unique applicable territory, each time with less interior borders, have obliterated the fragmentary categories that we handle, relating to sectors of activity, academic qualifications, professional profiles and areas of knowledge".

The proposal of a new type of technician with the responsibilities and capacities mentioned is a private opinion, that may not seem interesting to my colleagues nor deserving of debate, and whose practical materialization would, in any case, encounter a colossal resistance on the part of the regulations, institutions, and ideas established. But because of my age, just five years away from retirement and with nothing to gain, I will allow myself, and I hope that the reader will also generously allow me, to pose here

some ideas for a possible debate on the general pattern of infotechnology and on its impact in the technosocial environment, elaborated for many years and summarized in my recent book, titled like this article (see www.reduniversaldigital.com). The theoretical base of the book is an integral explanatory conception of the technological infrastructure that we are creating and of the forces of social transformation that it generates.

Information society and infomass

At present, I do not like a lot the term "information society" minted during the late 60's, but now very eroded after so much repetition in the mass media and a little degenerated since, with the globalization, has passed in the European Union to become another chapter of the political economy.

Its more evident characteristic is the infomass – the amount of information –produced, either registered or in circulation that, reduced to its binary terms, is now measured in exabytes. An exabyte is one billion of gigabytes or one million of terabytes, a 1 followed by 18 zeros if measured in bytes. The School of Information Management and Systems (SIMS), at Berkeley University, estimates that the new infomass registered in the world during 2002 in the four types of physical media, paper, film, optic and magnetic, totalized 5 exabytes, with a 30% growth since 1999, equivalent to the information contained in 37,000 libraries identical to that of the United States Congress. In the same period, the flows of new information, circulating in the networks of telephone, radio, TV and Internet, rocketed to the 18 exabytes, 98% out of them corresponding to telephone calls and text messages, in fixed or mobile lines, person-to-person communication primarily (see: http://www.sims.berkeley.edu/research/projects/how-much-info-2003/execsum.htm).

I confess that, as a bitter user of the Internet, when I recall that 98%, I still feel some sense of surprise and I must verify once more than I have not mistaken the numbers. Given that I do not have the means to contribute more solvent figures, I must rely on the estimations of the SIMS, just as they appear in their report, that throw a vast difference, in rough units of bytes, between the telephone flow and the Internet flow, the second one been produced in a 3% proportion of the first one. The Internet flow reached 533.000 terabytes, approximately 400.000 terabytes out of which constituted the total volume of electronic messages, some 31.000 million daily messages (original, not copies), sent at that time by some 600 millions Internet users (in Africa only some 6 millions).

The evolution of the telephone is one of the most exciting stories of the technology. I'm considering the history of technology, as a whole, not just infotechnology. When it was invented in 1876, Graham Bell tried to create a system of hearing for the deaf people. In 2004, 128 years later, it has become a light apparatus of around 100 grs., without cables, with screen, that functions as a radio, harbors very integrated electronic circuits, that is a multimedia computerized device connectable to various types of networks, e.g. Internet, multifunctional (radio, games, calculating, agenda, music player, e-mail, etc., and telephone as well!). People spend more time looking at and typing and sending messages than holding them by their ear, as it was in its origins.

During 2003, 85 million telephones with digital camera were sold in the world and this year (2004) it is estimated that some 160 million units will be sold. By the time I'm writing this article, there is an TV commercial campaign from a Spanish mobile operator, that stands something like this: "The mobile communication is changing your world: to speak, to see, to feel ..." In September 21, 2004, the same operator announced in a daily national newspaper a device, "that allows you to see your emails and the attached files anywhere"... "you will have in your hand all the services of a mobile phone and a PDA in a single device. You will turn any place into your own office". The following day I showed in my class that device, that was passed from hand to hand, to see what my students believed of that small object. They said it was a computer, a calculator, an agenda, a PDA, but no one of them happened to think it was a telephone.

The exponential and diversified transformation of these types of mobile devices in less than 10 years, joined to the tremendous establishment of the telephone, has became them into key instruments of the technological infrastructure for the information society, that I have ended up, after many years thinking about it, visualizing as a Digital Universal Network.

Such a recent and spectacular transformation is due to an unprecedented technical and scientific productivity, fueled by immense economic machinery that has drastically shortened the cycle of other more modern technologies, such as the computer's for instance. Thus, the history of the computer is enclosed in a short interim of slightly more than 50 years, lived along the last tenth part of the existence of the printed book, and regarding the Web of Internet, it occupies little more than its two hundredth parts; the personal computer is hardly 30 years old.

It does not seem necessary, nor do I have the space to do so, to describe details of the fertile combination and the marriage of telephony with informatics, that was first called teleprocessing, telematics later, or to stand out the role of the telephone networks as communication networks for the Internet, that is extended now to an Internet with mobile devices (Mobinet) or the broadband, with the ADSL technology. It must be said, nevertheless, the technical impact of the Internet phone system or VoIP technology (Voice over Internet Protocol), that converts the words in rows of bits, holds them in packages properly labeled, and treats them as any other Internet package all the way to its destiny, to reconstruct them there, and transform them into sound. Is this the telephone technology of the future? An article in The Economist, in 2001, read the following: "Must a network of commutation packages have to be built from zero, totally new and much greater, that combines the scalability of the Internet with the quality and the global reach of the telephone system".

The pyramid of digital platforms

Up to now, the only elements of the infotechnological infrastructure that I have mentioned, aside from the basic electronic microcircuits, have been the mobile telephones, the laptop and the personal computer, the Web and its corresponding networks. It is well known, nevertheless, that the arsenal of available media is very broad, but it would be more fruitful to have a conceptual map of how they are structured. And in my opinion, the best way to begin to appreciate its structural makeup is to point out its role as elements of various architectures of networks.

In 1997, a group of the best computer scientists and engineers met in San José, California, to celebrate the fiftieth anniversary of the foundation of the ACM (Association for Computing Machinery) and to draw the tendencies of the following fifty years of computing science and engineering. Above all the others, the presentation of Gordon Bell and James Gray on the architecture of the cyberspace grasped my attention. I was especially sensitive to what they explained, because 10 years before, in 1987, I had published a book on personal computers, edited by Fundesco, Madrid, that carried the subtitle "Towards a world of computing machines".

In that book I developed extensively the concept of connectability (exo- and endoconnectability) of personal computers, to which I already predicted as nodes of future and dense computer and communication networks. Now, I saw Bell and Gray draw the outline of the cyberspace future more or less as an immense weaving of networks – wide area networks (WAN), local area networks (LAN), system area networks (SAN), home area networks (HAN) and body or personal area networks (BAN, or PAN) – in which "they would float", connected, every type of computer platforms. Or digital platforms, extending the concept to cover to platforms that, if they are not digital in their origin, they tend to be in part or in their totality, incorporating computational elements.

The basic architecture is repeated as if was a fractal figure. Different platforms (computer, microprocessor, PDA, television set, telephone, music player, game console, sensor, etc.) are connected or they can be connected to a network and that network to another or some others. The platforms function with some kind of operating system and they execute programs/applications, with contents that we call games, images, texts, calculations, simulations, videos, measurements, etc. The platforms communicate with the human users by means of diverse interfaces and with the physical world by means of sensors, although there are also networks of sensors (sensor networks).

If we only look at digital platforms and we evaluate them demographically as if they were individuals of a population, we observe that they form a pyramid. In its summit we see great computers and even greater ones (of great power, we mean), designed for large scientific computations (genome, environmental calculations, physics of particles, etc.), that cost millions of dollars (or euros) and its small demographic density is counted by hundreds or thousands of units in the computer universe. Descending to the base, we find millions of PCs, telephones and similar devices that cost hundreds or tens of dollars, followed by devices such as those light implements known as information appliances, and ubiquitous computers, diverse microprocessors, "smart" memory cards, RFID chips (radio), etc., in price ranges of the scores of units and cents of dollar, aimed already or in a very immediate future to endow to the infotechnological infrastructure of the maximum social capillarity, even being embedded in the physical structures of the environment, in the personal clothing or in the interior of the bodies, for hundreds of thousands of millions of units in a few years.

Another metaphor in aid of the Digital Universal Network (DUN): The Global Ubiquitous Computer (GUC), of Hoare

In the middle of this decade we are entering a new phase of computing - ubiquitous computing or pervasive infotechnology-, in which the infotechnology materially disappears, to become part of the material infrastructure, so it's been refered to as

environmental intelligence, intelligent environments, sentient computing, and perceptual interfaces are designed sensitive to the attention, to the desires or to the emotions of the users. In this unexpected situation, a person, shared by many computers, will need to be helped by these.

Now, in order to speak of pervasive infotechnology, it is necessary that the networks reach or tend to reach all the places, that its coverage extends through space seamlessly until they connect with physical objects themselves, with the matter, because things already are, or they can be infiltrated by built-in instruments and this is something that has already begun to happen, although it's still in a embryonic phase, thanks to the mobile and wireless technologies of short or very short distance, e.g. Wi-Fi, Bluetooth, and others.

In February of 1998, to call this sensed expansion of the infotechnology, I utilized the concept of Total Digital Machine, that, later on, in 1999, convinced that its more important characteristic was its networked architecture, I changed to Digital Universal Network (DUN). Developing in large this concept of technological infrastructure and its social consequences has been a process that, as a professor, engineer and computing scientist, ¿perhaps already as a hybrid engineer?, I have lived during 2001, 2002 and 2003 with anxiety in my role as a divulgator, by fear of being labeled as a fiction writer, as a creator of gaseous concepts or something similar. Why? Because to dare to say that there is an important "thing," called Digital Universal Network, that nobody has seen nor heard of, might be taken as the occurrence of a young dazed mind or of a crazy, old man. I could not stop thinking of how I could justify myself.

But, finally, after many doubts I dared to do it, encouraged by a didactic purpose. On page 293 of that book I wrote the following: "The Digital Universal Network does not exist, and it does exist. Nobody has designed nor built it. It is being built in heterogeneous pieces, through innumerable contributions. But, in spite of the incompatibilities and problems with languages, systems, protocols, standards, codes, signals, circuits and a long etcetera, that somewhat embitter the day to day, we observe a non-stop convergence, in such a way that in the course of a few years we have all been able to experience the real sensation of progress in terms of global intercommunication, as if our devices were connected to transparent universal networks. The Internet is the paradigm that projects in people such a sensation. Because it does not exist, we say that the DUN is a metaphor, the expression of a complex entity in the process of formation, but of which we cannot draw a sketch or a diagram, since it is not a concrete system, but the convergent result of a myriad of systems and complex appliances that exist separately. We know some of them and we use them habitually". It's an enormous weaving of digital technology networks, almost imperceptible for our senses, hidden in radio waves and invisible circuits, and it is its emergency, as a whole or system, that we have difficulties to seize.

Not long ago and by pure coincidence, surfing the Web, I discovered some words by Tony Hoare, dated June 8, 2004, and I confess that because his authority made me feel more protected, being done they have the same metaphorical air as that from my concepts of Total Digital Machine or DUN. I do not believe that anyone will dare to qualify Hoare, the great computer scientist, pioneer of programming, winner of the Turing Award in 1980, knighted gentleman in England as of March of 2002, of being a crazy old man. He has proposed that in order to better understand a world massively

populated with computers, like it is estimated it will be by 2020, we should not see it as something that contains many discrete computers, but as a Global Ubiquitous Computer (GUC).

A New Technosocial Environment (NET, in Spanish acronym)

Different journalists have asked me "Do you believe that there is something beyond Internet? Is the Digital Universal Network the following step to the Internet? Summarizing my answers, I have responded that beyond the Internet is the new generation Internet, with more powerful technology, but that the Internet is only a part, although an essential part, of the Digital Universal Network, which is a heterogeneous assembly composed by multiple and different networks, such as but not limited to, local area networks, fixed telephone networks, mobile phone networks, Wi-Fi networks, GPS satellite networks, networks of electric power – grids – with PLC technology (broadband through the electrical socket), body networks, system networks (e.g.: within a car), TV closed circuits networks, etc., every day more digital (including radio and television) and interoperable.

Most importantly, nevertheless, is to recall that the life of the human species can be judged as a process of co-evolution with diverse environments and the present environment is being built as the generating uterus of new social forms, as are, according to the philosopher J. Echeverría in the book "Los Señores del Aire: Telépolis y el Tercer Entorno", Ed. Destino, 1999, the tele-work, the tele-money, the tele-crime, the tele-education, the tele-war, the tele-newspaper, and a long list. One of the journalists asked me if we ran the risk of slowly moving away from reality to live in a virtual environment. My answer: It is best not to contrast reality and virtuality, as if they were two antagonistic concepts. If virtuality means that we lose physical contact with people, with things, with nature, through the senses, we are certainly becoming more and more virtual, but communicating through a mobile phone, working or purchasing through the Internet has real effects. What happens is that reality is increasingly becoming more virtual.

Virtuality is one of the twenty properties of the New Technosocial Environment (NET) that I have defined and explained in my book as the keys of the transformations, that, in coevolution with the Digital Universal Network, society is experiencing. As a preliminary orientation for the reader interested in deepening more in this matter, I relate them subsequently, grouping them inside each category of transformation. Time-space transformations: instantaneity, distality, ubiquity, mobility and reticularity. Transformations in the body, in the sensory relations, in the borders of personal action and identity: representality, protesicity, multisensoriality, interactiveness and virtuality. Transformations toward a unified language of the ways of collecting and managing information: digitality, potentiality, omniprocessality and analog-digitality. Transformations in the hierarchies of intellectual relation with the technological environment and with objects: neurality and intelectivity. Barriers in the user interfacing: intangibleness, hermeticity, discontinuity and feudality.

To conclude, I wish to highlight the curious brotherhood, hidden at first sight, between the denomination of the concepts of Digital Universal Network and the "metaphysical" properties of the environment generated, which, in Spanish, acronyms NET, stand for Network. The concept of network is being supported by some thinkers and scientists as

the new general conceptual paradigm. I think that my book is impregnated of that paradigm. It is frequently told, for example, that the new economy consists of a meta-network of complex human and technological interactions. And for F. Capra, in his recent book titled "The hidden connections", Spanish edition by Anagrama, 2003, the network is also a common pattern to all that lives: "organisms can be understood in terms of networks of cells, organs and systems of organs, like networks of molecules".